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Juvenile Height Growth of Four Species on Four Sites in the CWHb1 Variant

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Juvenile Height Growth of Four Species on Four Sites in the CWHb1 Variant

by
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ABSTRACT

Height growth curves to age 26 years are developed and compared for Douglas-fir, Sitka spruce, western hemlock, and western redcedar planted on four different sites within the Windward Submontane Maritime Wetter Coastal Western Hemlock (CWHb1) variant on the west coast of Vancouver Island, British Columbia. Douglas-fir was taller than all other species in all sites, followed in turn by western hemlock, Sitka spruce, and western redcedar. It was also noted that salal competition for nutrients may have impeded the growth of most tree species, and that stem defects were prominent in Douglas-fir and Sitka spruce. The developed juvenile height growth curves, which are similar in shape to selected published growth curves, should be useful in evaluating early stand growth, and in determining height growth in immature stands within the CWHb1 variant.

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TABLE OF CONTENTS

ABSTRACT iii

ACKNOWLEDGEMENTS iii

INTRODUCTION 1

STUDY AREA 1

STUDY DESIGN AND ASSESSMENT 2

ANALYSIS 4

Height Growth Curves and Comparisons 4

Salal Competition and Stem Defects 4

RESULTS 5

Height Growth Curves and Comparisons 5

Salal Competition and Stem Defects 10

DISCUSSION 11

Height Growth Curves and Comparisons 11

Salal Competition and Stem Defects 11

CONCLUSIONS 11

LITERATURE CITED 12

APPENDICES

1 Height growth curve coefficients by species and site unit 13

2 Stem defects by species, location, and site unit 14

3 Average branch dimensions in Franklin River plots by species and spacing at age 25 years 15

TABLES

1 EP 571 experimental design 2

2 EP 571 seed sources 3

3 EP 571 plot assessment and maintenance 3

4 Site units identified in EP 571 5

5 Periodic height growth by species and site unit 9

6 Salal cover by tree species and site unit at age 26 years 10

FIGURES

1 Douglas-fir height growth curves 6

2 Western redcedar height growth curves 6

3 Western hemlock height growth curves 6

4 Sitka spruce (damaged) height growth curves 6

5 Sitka spruce (undamaged) height growth curves 7

6 Height growth curves on Site Unit 2 by species 7

7 Height growth curves on Site Unit 3 by species 7

8 Height growth curves on Site Unit 4 by species 7

9 Height growth curves on Site Unit 6 by species 8

INTRODUCTION

Aside from stand density, species selection is one of the major factors a forester can manipulate to influence future yield and value of forests. The relative height growth performance of various tree species on common sites with well-defined site quality is, therefore, of considerable interest.

In this paper, we have developed and compared the juvenile height growth curves of Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco), Sitka spruce *(Picea sitchensis* [Bong.] Carr), western hemlock *(Tsuga heterophylla* [Raf.] Sarg.), and western redcedar *(Thuja plicata* Donn.) planted on four site units within the Windward Submontane Maritime Wetter Coastal Western Hemlock (CWHb1) variant (Klinka *et al.* 1984, p. 131) on the west coast of Vancouver Island,British Columbia. The paper is based on 26-year data and observations from B.C. Forest Service Research Branch Experimental Project 571.

STUDY AREA

Experimental project (EP) 571 was established in 1962 at three locations on the west coast of Vancouver Island: Port Renfrew, Franklin River, and Mooyah Bay. The objectives of the study were to obtain information on the silvics and silviculture of four species: Douglas-fir, Sitka spruce, western redcedar, and western hemlock, planted on a variety of sites at three initial spacing levels (2.7 x 2.7 m; 3.7 x 3.7 m; 4.6 x 4.6 m).[1] At each location,experimental plots are distributed across a range of aspects: north-facing slope, south-facing slope, and valley bottom. The study areas,located within the CWHb1 variant, initially supported old-growth stands of western hemlock, western redcedar, amabilis fir (*Abies amabilis* [Dougl.]Forbes), and occasional Douglas-fir and Sitka spruce. The areas were logged between 1958 and 1960 and slashburned to various extents in 1961. The Douglas-fir site index estimate ranged from 25 to 37 m at 50 years breast-height age (based on Bruce's [1981] site curves). The site, soil, and vegetation description and site diagnosis conducted in the study areas between 1984 and 1986 indicated that the soil moisture and nutrient regimes ranged from slightly dry and nutrient-very poor to very moist and nutrient-very rich; the texture was either loamy, sandy, or silty, with a rooting depth of 20-110 cm; the elevation ranged from 20 to 375 m, with 0-65% slope; and the understorey vegetation noted was that common to the CWHb1 sites (see Klinka *et al.* [1984, p. 30]).[2]

The climate at all study sites is cool and wet, with frequent summer fogs. In the growing season (May to September), there are no significant climatic differences among the locations, although Franklin River receives slightly less precipitation in that period. About 17-22% of the total annual precipitation (2800 mm) falls during the growing season when the mean daily temperature is above 10°C. Snow does not lie on the ground for extensive periods of time and occurs only intermittently during the winter (December to February).

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[1] J.C. Hetherington. 1961. Trials of tree species and initial spacing on the west coast of Vancouver Island. Working plan EP 571. B.C. Min. For. Res. Branch, Victoria, B.C.

[2] The site descriptions were conducted by G. Krumlik, K. Falkiner, and A. Scagel.

TABLE 2. EP 571 seed sources

Species	Seedlot no.	Seed source	
		Location	Elevation (m)
Douglas-fir	B2/490/59	Gold River	244
Western redcedar	B2/483/59	Upper Klanawa	213
Sitka spruce	B2/486/59	Sarita River	91
Western hemlock	B4/MD/56	Great Central Lake	122-180

TABLE 3. EP 571 plot assessment and maintenance

Date	Location	Seedling survival	dbh[a]	Height	Maintenance
Spring 1962	PR,FR,MB[b]	/			planted[c]
Spring 1963	PR,FR,MB	/			replanted[e]
Fall 1967	PR,FR	/		/	
Summer 1968	PR,FR				weeded
Summer 1969	PR,FR				weeded
Summer1970	PR,FR		/	/	cleaned[d]
Fall 1975	PR		/	/	cleaned[f]
Fall 1977	FR		/	/	cleaned[f]
Fall 1979	PR		/	/	cleaned
Fall 1981	FR,MB		/	/	cleaned
Summer 1983	PR		/	/	cleaned
Spring1985	FR		/	/	cleaned
Fall 1985	MB		/	/	cleaned

[a] dbh = diameter at breast height (4.5 ft) outside bark.
[b] PR = Port Renfrew; FR = Franklin River; MB = Mooyah Bay.
[c] Planted with 2+0 bareroot stock.
[d] Coniferous regeneration was cut; salal and other lesser vegetation was not cleared.
[e] Replanted with surplus seedlings left on site after the 1962 planting.
[f] Trees were pruned to breast height for measurement access.

ANALYSIS

Height Growth Curves and Comparisons

Based on the plot soil moisture and nutrient regime classification, each plot was assigned to a site unit[4] using the edatopic grid No. 9 of Klinka *et al.* (1984, p. 30). Height growth curves were then developed and compared by species and site unit as follows.

First, unmeasured tree heights were estimated from appropriate height-diameter curves fitted separately for each measurement period for each plot. Top height was calculated for each plot as the arithmetic average total height (measured or estimated from a height-diameter curve) of the 100 trees per hectare of largest diameter (i.e., 4, 6, and 10 trees per 2.7 x 2.7 m, 3.7 x 3.7 m, and 4.6 x 4.6 m plots, respectively).

Next, height growth curves — regressions of top height versus total age from seed — were developed by fitting the following model to each species site unit data set (containing at least three plots):

$$\ln(y) = a + b^{*} \ln(x)$$

where

y = top height in metres

x = total age from seed in years

ln = natural logarithms

Model (1) was fitted by ordinary linear least squares.

Then the resulting height growth curves of the four species to age 26 years were graphically compared among the identified site units, and with the U.K. Forestry Commission curves (Hamilton and Christie 1971) and selected curves published in the Pacific Northwest for Douglas-fir (Bruce 1981), Sitka spruce (Barker 1983), western hemlock (Wiley 1978), and western redcedar (Kurucz 1978). In addition, top height at total age 8 years and the top height periodic annual increment for the period age 8-26 years were summarized by species and site unit.

Salal Competition and Stem Defects

Based on the 1984/86 plot vegetation descriptions, the frequency of occurrence of salal (*Gaultheria shallon* Pursh.) was summarized by tree species, site unit, and percentage salal cover class. No quantitative plant cover determinations were made.

From the tree condition data collected between 1967 and 1985, summaries were made of stem defects (lean, sweep, broken top, twin stems, forking, crookedness, and poor top) by species and site unit. A defect frequency index, defined here as the ratio of total count of defects to total number of observed trees, was calculated for each species and site unit. As well, the Franklin River 1985 assessment data on branch characteristics (frequency and size) were summarized by species and initial spacing.

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[4] A site unit represents a grouping of closely related forest sites which can support forest stands of the same composition and structure, have similar production potential, and can be managed by the same silvicultural system (Klinka *et al.* 1984, p. 110).

RESULTS

Four major site units (i.e., site units with three or more plots within the CWHb1 variant) were identified in EP 571 (Table 4). The results of the height growth analysis and salal competition and stem defects are summarized below by species and the identified site units.[5]

TABLE 4. Site units identified in EP 571

CWHb1 site unit no.	Soil moisture regime	Soil nutrients regime
2	slightly dry to fresh	very poor to medium
3	fresh to moist	very poor to medium
4	fresh to moist	medium to very rich
6	moist to very moist	medium to very rich

Height Growth Curves and Comparisons

Regression equations relating top height to total age were developed (Appendix 1) and depicted graphically for each species and site unit (Figures 1-9). The curves were developed on the basis of data collected after 1967, and therefore sometimes exhibit erratic patterns below age 8. The height growth of Douglas-fir is superior to the other species on all the observed site units to age 26 (Figures 6-9; Table 5). At any given age or site unit, Douglas-fir is considerably taller than western hemlock, which in turn is taller than western redcedar. (Sitka spruce tree heights have been affected by spruce weevil (*Pissodes strobi* Peck.) attacks on the leader.) As well, there is less variation in the height growth curves among site units in Douglas-fir than in any other species.

For all species, juvenile height growth is outstanding in the moist to very moist and nutrient-medium to very rich sites (Site Unit 6) (Figure 9),and is least on the slightly dry to fresh and nutrient-very poor to medium sites (Site Unit 2) (Figure 6; Table 5).

Compared with the selected height growth curves published in the Pacific Northwest and the U.K. Forestry Commission, the EP 571 height growth curves conform in shape in most sites for all the species (Figures 1-5) except Sitka spruce, which has obviously been significantly affected by the spruce weevil (Figures 4 and 5).

[5] Results of other growth and yield analyses are provided in the file report: "Early growth of Douglas-fir, Sitka spruce, western hemlock, and western redcedar planted at three spacings on Vancouver Island," by S.A.Y. Omule. 1987. B.C. Min. For. Res. Branch, Victoria, B.C. Review Manuscript.

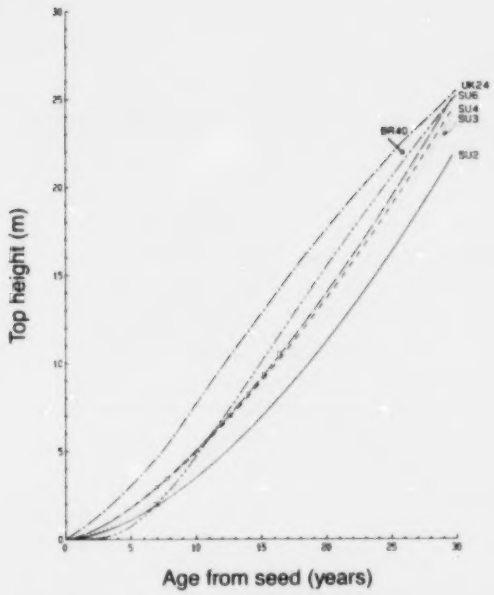

FIGURE 1. Douglas-fir height growth curves.

SU Site Unit.
SU2 slightly dry to fresh and nutrient-very poor to medium soils in the CWHb1 variant (Klinka et al. 1984).
SU3 fresh to moist and nutrient-very poor to medium soils in the CWHb1 variant.
SU4 fresh to moist and nutrient-medium to very rich soils in the CWHb1 variant.
SU6 moist to very moist and nutrient-medium to very rich soils in the CWHb1 variant.
BR40 Bruce (1981) site index curve 40 m at total age 50.
UK24 U.K. Forestry Commission curve for yield class 24.

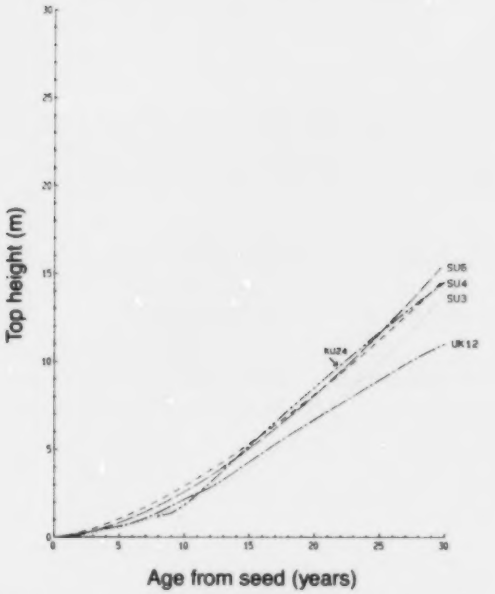

FIGURE 2. Western redcedar height growth curves.

SU Site Unit.
SU2 slightly dry to fresh and nutrient-very poor to medium soils in the CWHb1 variant (Klinka et al. 1984).
SU3 fresh to moist and nutrient-very poor to medium soils in the CWHb1 variant.
SU4 fresh to moist and nutrient-medium to very rich soils in the CWHb1 variant.
SU6 moist to very moist and nutrient-medium to very rich soils in the CWHb1 variant.
KU24 Kurucz (1978) site index curve 24 m at total age 50.
UK12 U.K. Forestry Commission curve for yield class 12

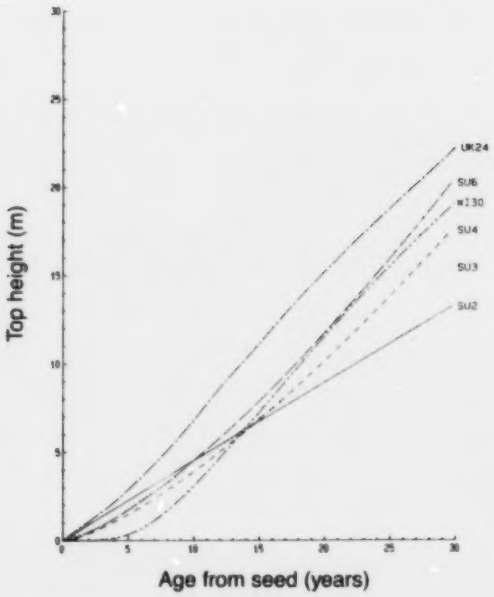

FIGURE 3. Western hemlock height growth curves.

SU Site Unit.
SU2 slightly dry to fresh and nutrient-very poor to medium soils in the CWHb1 variant (Klinka et al. 1984).
SU3 fresh to moist and nutrient-very poor to medium soils in the CWHb1 variant.
SU4 fresh to moist and nutrient-medium to very rich soils in the CWHb1 variant.
SU6 moist to very moist and nutrient-medium to very rich soils in the CWHb1 variant.
W130 Wiley (1978) site index curve 30 m at total age 50.
UK24 U.K. Forestry Commission curve for yield class 24.

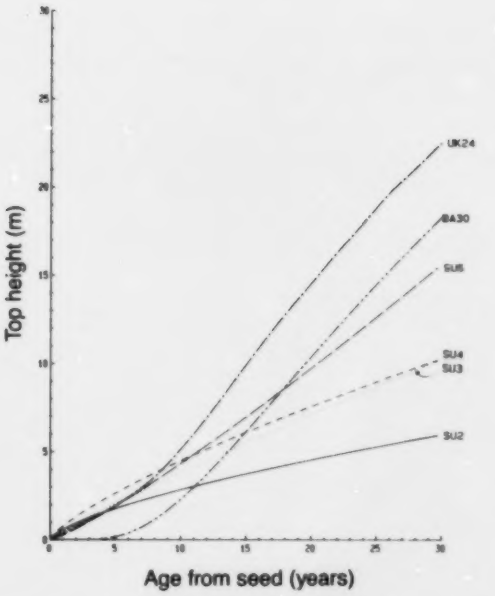

FIGURE 4. Sitka spruce (damaged) height growth curves.

SU Site Unit.
RU2 slightly dry to fresh and nutrient-very poor to medium soils in the CWHb1 variant (Klinka et al. 1984).
SU3 fresh to moist and nutrient-very poor to medium soils in the CWHb1 variant.
SU4 fresh to moist and nutrient-medium to very rich soils in the CWHb1 variant.
SU6 moist to very moist and nutrient-medium to very rich soils in the CWHb1 variant.
BA30 Barker (1983) site index curve 30 m at total age 50.
UK24 U.K. Forestry Commission curve for yield class 24.

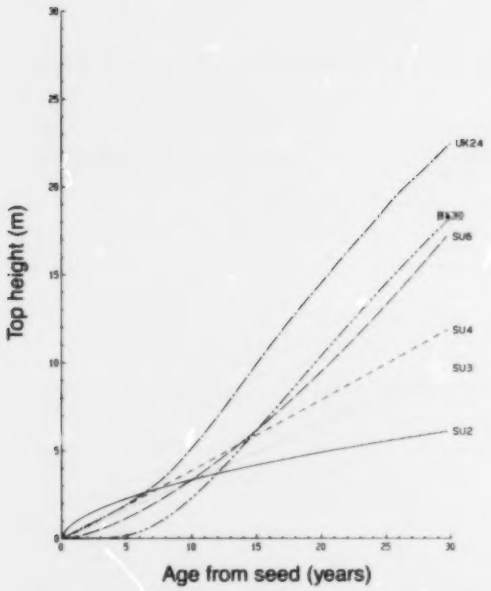

FIGURE 5. Sitka spruce (undamaged) height growth curves.

SU Site Unit.
SU2 slightly dry to fresh and nutrient-very poor to medium soils in the CWHb1 variant (Klinka et al. 1984).
SU3 fresh to moist and nutrient-very poor to medium soils in the CWHb1 variant.
SU4 fresh to moist and nutrient-medium to very rich soils in the CWHb1 variant.
SU6 moist to very moist and nutrient-medium to very rich soils in the CWHb1 variant.
BA30 Barker (1983) site index curve 30 m at total age 50.
UK24 U.K. Forestry Commission curve for yield class 24.

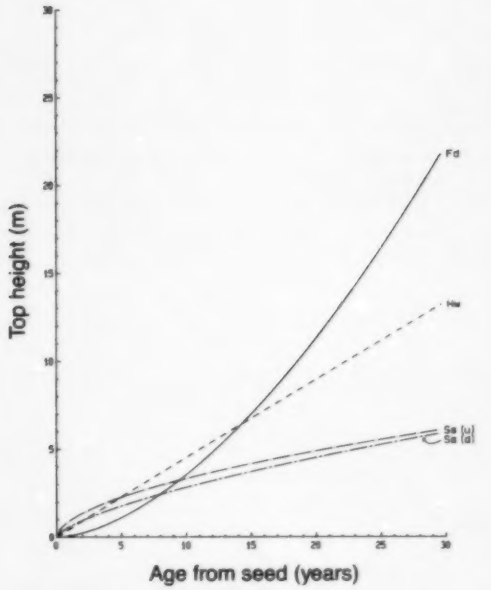

FIGURE 6. Height growth curves on Site Unit 2 by species.

Site Unit 2 slightly dry to fresh and nutrient-very poor to medium soils in the CWHb1 variant (Klinka et al. 1984).
Fd Douglas-fir; Hw western hemlock, Se(u) Sitka spruce (unweevilled trees); Se(d) Sitka spruce (weevilled trees).

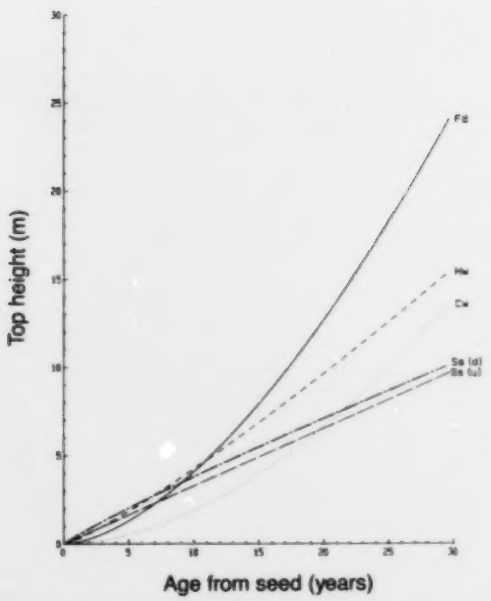

FIGURE 7. Height growth curves on Site Unit 3 by species.

Site Unit 3 fresh to moist and nutrient-very poor to medium soils in the CWHb1 variant (Klinka et al. 1984).
Fd Douglas-fir; Hw western hemlock; Se(u) Sitka spruce (unweevilled trees); Se(d) Sitka spruce (weevilled trees); Cw western redcedar.

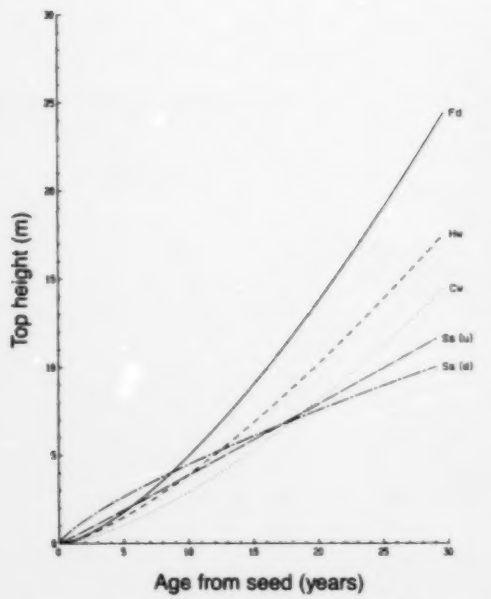

FIGURE 8. Height growth curves on Site Unit 4 by species.

Site Unit 4 fresh to moist and nutrient-medium to very rich soils in the CWHb1 variant (Klinka et al. 1984).
Fd Douglas-fir; Hw western hemlock; Se(u) Sitka spruce (unweevilled trees); Se(d) Sitka spruce (weevilled trees); Cw western redcedar.

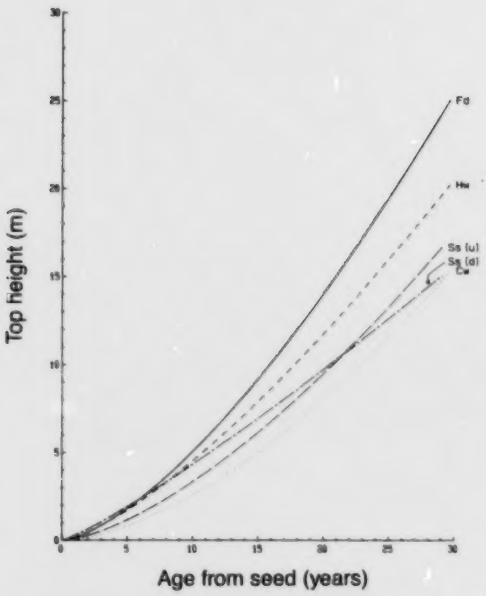

FIGURE 9. Height growth curves on Site Unit 6 by species.

Site Unit 6 moist to very moist and nutrient-medium to very rich soils in the CWHb1 variant (Klinka et al. 1984).
Fd Douglas-fir; Hw western hemlock; Ss(u) Sitka spruce (unweevilled trees); Ss(d) Sitka spruce (weevilled trees); Cw western redcedar.

TABLE 5. Periodic height growth by species and site unit

Species and site unit	No. of plots[a]	Average height[b] at age 8 yr (m)	Periodic annual height growth 8-26 yr (m/yr)
Douglas-fir			
2	3	2.5(0.6)[c]	0.75(.06)
3	10	3.0(0.3)	0.86(.03)
4	4	3.7(0.2)	0.88(.02)
6	8	3.5(0.2)	0.90(.02)
Sitka spruce — weevilled			
2	-		
3	11	3.3(0.2)	0.35(.03)
4	3	3.9(0.4)	0.51(.08)
6	9	3.4(0.1)	0.57(.03)
Sitka spruce — unweevilled			
2	-		
3	11	2.7(0.2)	0.33(.03)
4	3	3.1(0.2)	0.47(.07)
6	9	2.5(0.4)	0.55(.03)
Western hemlock			
2	3	3.2(0.4)	0.55(.06)
3	9	3.2(0.2)	0.59(.05)
4	5	3.2(0.3)	0.67(.05)
6	9	3.1(0.2)	0.73(.03)
Western redcedar			
2	-		
3	8	1.3(0.1)	0.37(.05)
4	5	1.8(0.1)	0.55(.04)
6	9	1.7(0.2)	0.54(.02)

[a] The Mooyah Bay plots are not included.
[b] Top height: tallest 100 trees per hectare at age 8 yr and largest 100 trees per hectare by diameter at age 26 yr.
[c] The values in brackets are standard errors.

Salal Competition and Stem Defects

The 1984-1986 plot site diagnosis indicated that, unlike the Douglas-fir plots, many of the Sitka spruce, western hemlock, and western redcedar plots were largely dominated by salal understorey. Overall, about 6, 38, 39, and 60% of the plots were judged to have a salal cover of 75% or more in the Douglas-fir, Sitka spruce, western hemlock, and western redcedar plots, respectively (Table 6). In general, for all species, there was less salal cover on the wetter and richer sites than on the drier and poorer sites (Table 6).

The main stem defects for all species were broken tops, crookedness, and forking which, when measured by a defect frequency index, increased with increase in site moisture and nutrients. The defects were more frequent in Douglas-fir and Sitka spruce (see Appendix 2). On average over all the spacing levels, Sitka spruce had the most branches (10) at the whorl nearest breast height, followed by Douglas-fir (8), western hemlock (6), and western redcedar (5). For each spacing, the branch diameters were slightly larger in Sitka spruce and Douglas-fir than in western hemlock and western redcedar (see Appendix 3).

TABLE 6. Salal cover by tree species and site unit at age 26 years

Tree species and site unit	Percentage salal cover class (%)				
	0-24	25-49	50-74	75+	Total
	Number of plots				
Douglas-fir					
2	2	0	0	1	3
3	9	1	5	1	16
4	4	1	0	0	5
6	8	0	0	0	8
Total	23	2	5	2	32
Sitka spruce					
2	0	0	0	3	3
3	5	1	5	5	16
4	2	0	0	2	4
6	6	0	1	2	9
Total	13	1	6	12	32
Western hemlock					
2	0	1	1	1	3
3	2	0	2	5	9
4	3	0	0	2	5
6	6	0	1	2	9
Total	11	1	4	10	26
Western redcedar					
2	0	0	0	2	2
3	1	0	2	7	10
4	1	0	2	7	10
6	2	2	3	3	10
Total	4	2	7	19	32

DISCUSSION

Height Growth Curves and Comparisons

Although the height growth curves developed conform in shape to some published height curves, even more important is that they were developed on a site-specific basis, enabling more site-specific decision-making. The main potential uses of these growth curves (Figures 1-9) are: 1) for developing standards for an objective evaluation of juvenile stand height growth; and 2) for estimating height growth on cutover areas from indicator plant species and/or soil factors. The early growth trends demonstrated in this study may also have an impact on tree species selection for reforestation.

Salal Competition and Stem Defects

The results of this study indicate that Douglas-fir has outperformed all the other species on all sites in terms of height growth to age 26 years. However, several uncertainties, such as the effects of burning, planting stock, provenance, and salal competition, hinder a complete and convincing explanation of the results of species performance to date. In particular, as indicated by the salal presence and vigour (Table 6), it appears that the early growth of western hemlock, western redcedar, and Sitka spruce (spruce weevil attack notwithstanding) may have been impeded by competition with salal for nutrients. These tree species, unlike Douglas-fir, were probably unable to compete effectively with salal and form adequate canopy to shade it at the wider spacings, although they may outgrow salal faster if planted at tighter initial spacings (e.g., the 1.2- to 1.5-m spacing recommended for western redcedar by Minore [1983, p. 48]).

Aside from height growth performance, the effect of distorted growth symptoms on final yield (Carter and Klinka 1986) is also of interest on some sites within the CWHb1 variant. Stem form defects have been observed in all the species to varying degrees (Appendices 2 and 3). Some of these defects will probably persist, increase with age, and thus affect wood quality (Carter and Klinka 1986). In particular, the impact of the weevil attack on Sitka spruce stem quality and growth appears to be substantial and irreversible. As recommended by Heppner and Wood (1984), unless the weevil control techniques or appropriate provenances are redefined, Sitka spruce should probably not be planted within the CWHb1 high hazard zones (Heppner and Wood 1984, Figure 6).

CONCLUSIONS

Results for the range of treatments and conditions in this study indicated that:

1. Detectable differences exist in the juvenile height growth of Douglas-fir, Sitka spruce, western hemlock, and western redcedar at common sites within the CWHb1 variant.
2. For all the species, the height growth rates were consistently lower in Site Unit 2 (slightly dry to fresh and nutrient-very poor to medium soils), than in Site Unit 6 (moist to very moist and nutrient-medium to very very rich soils)but on both sites the height growth rate ranking among the species was identical. In decreasing order of magnitude the ranking was: Douglas-fir, western hemlock, Sitka spruce (undamaged), and western redcedar.
3. The juvenile height growth curves developed here conform in shape with selected curves published in the Pacific Northwest and the U.K. Forestry Commission.
4. The early height growth of western hemlock, western redcedar, and Sitka spruce planted at wide initial spacing (greater than 3 x 3 m), unlike Douglas-fir, appears to be impeded by competition with salal for nutrients.
5. Generally, western hemlock appears to have the least number of stem form and branch defects compared to Douglas-fir or western redcedar. (The Sitka spruce defects appear to have been caused largely by the spruce weevil.)

It is difficult to say how representative these results are of the plantations established and maintained operationally on similar sites in the same areas. However, the juvenile height growth curves and the discussion presented here should be useful in assisting the forest manager in species selection, in evaluating early stand growth of plantations, and in determining height growth performance within the CWHb1 variant on the west coast of Vancouver Island.

LITERATURE CITED

Barker, J.E. 1983. Site index relationships for Sitka spruce, western hemlock, western redcedar and red alder. Moresby Tree Farm Licence #24, Queen Charlotte Islands. File report, Western Forest Products Ltd., Vancouver, B.C.

Bruce, D. 1981. Consistent height-growth and growth-rate estimates from remeasured plots. For. Sci. 27 (4):711-725.

Carter, R.E. and K. Klinka. 1986. Symptoms and causes of distorted growth in immature forest stands in coastal British Columbia. B.C. Min. For., Land Manage. Rep. No. 39. 61 p.

Hamilton, G.J. and J.M. Christie. 1971. Forest management tables (metric). Booklet 34. U.K. Forestry Commission, London, England.

Heppner, D.G. and P.M. Wood. 1984. Vancouver region Sitka spruce weevil survey results (1982-1983) with recommendations for planting Sitka spruce. B.C. Min. For., For. Serv. Int. Rep. PM-V-5.

Klinka, K., R.N. Green, P.J. Courtin, and F.C. Nuszdorfer. 1984. Site diagnosis, tree species selection, and slashburning guidelines for the Vancouver Forest Region. B.C. Min. For., Land. Manage. Rep. No. 25. 180 p.

Kurucz, J.F. 1978. Preliminary polymorphic site index curves for western redcedar — *Thuja plicata* Donn — in Coastal British Columbia. For. Res. Note 3, MacMillan Bloedel Ltd., Vancouver, B.C.

Minore, D. 1983. Western redcedar —a literature review. U.S. Dep. Agric. For. Serv. Pac. Northwest For. Exp. Stn., Gen. Tech. Rep. PNW-150.

Wiley, K.N. 1978. Site index tables for western hemlock in the Pacific Northwest. Weyerhaeuser Forestry Paper No. 17. Weyerhaeuser Company, Western Forestry Research Center, Centralia, Wash. 98531. 27 p.

APPENDIX 1. Height growth curve coefficients by species and site unit[a]

Species and Site Unit	a	b	r^2	n[b]	SEE[c]	CV[d]
Douglas-fir						
2	-2.58023045	1.66961921	.910	15(3)	.2222000	11.5
3	-2.35337778	1.63233389	.934	65(16)	.1844400	8.4
4	-1.76867632	1.46393817	.980	22(5)	.0893620	4.0
6	-1.77246279	1.47254816	.979	40(8)	.0916004	4.1
Western redcedar						
3	-3.52869239	1.81020876	.928	35(8)	.2220323	16.5
4	-2.29297177	1.46410359	.941	41(10)	.1593352	8.8
6	-2.77907489	1.62496396	.898	44(10)	.2319914	14.3
Western hemlock						
2	-0.75579228	0.98441355	.721	12(3)	.2684311	13.4
3	-1.27968721	1.18411267	.861	45(9)	.1953373	10.2
4	-1.80848431	1.37808993	.938	20(5)	.1565906	8.0
6	-1.66221601	1.37703012	.953	43(9)	.1308430	6.3
Sitka spruce — undamaged						
2	-0.06532405	0.55282941	.526	12(3)	.2208282	15.0
3	-1.09243052	0.99225923	.792	68(16)	.2159076	13.1
4	-1.00917688	1.02716424	.916	17(4)	.1329468	7.3
6	-2.25641598	1.50419793	.609	44(9)	.4456609	26.0
Sitka spruce damaged (weevilled)						
2	-0.50431256	0.67291993	.308	12(3)	.4017144	29.3
3	-0.72672652	0.89778472	.761	68(16)	.2139045	12.1
4	-0.23502449	0.75412625	.728	17(4)	.1950945	10.6
6	-1.21928755	1.16644693	.930	44(9)	.1358090	7.0

[a] The linear equation:ln (top height) = a + b ln (total age) was fitted by ordinary least squares; top height is in metres and total age in years.
[b] n = total number of remeasurements; the values in brackets are total number of sample plots.
[c] SEE = estimate of the standard deviation on ln (top height) around the regression line.
[d] CV = coefficient of variation = SEE as percentage of the mean of ln (top height).

APPENDIX 2. Stem defects by species, location, and site unit

Site Unit	d_f*	No. stems with defect							Total no.	
		Broken top	Crooked	Forked	Lean	Poor top	Sweep	Twin	Defects	Trees
Douglas-fir										
Franklin River										
2	.088	0	2	1	1	0	0	0	4	45
3	.164	0	19	28	1	3	2	0	53	323
4	.174	0	13	3	0	0	0	0	16	92
6	.368	6	21	33	1	3	2	1	67	182
Port Renfrew										
2	.011	0	1	0	0	0	0	0	1	85
3	.101	9	0	0	0	1	0	0	18	178
4	.278	3	6	9	1	0	8	0	27	97
6	.128	1	5	8	4	2	4	0	24	188
Mooyah Bay										
3	.017	2	1	0	0	0	1	0	4	237
4	.021	1	0	0	0	0	0	0	1	47
Western redcedar										
Franklin River										
2	.021	0	1	0	0	0	0	0	1	481
3	.109	0	1	0	0	0	1	3	5	46
4	.107	6	16	4	1	3	0	6	36	338
6	.652	38	33	30	1	12	2	4	122	187
Port Renfrew										
3	.095	9	3	3	0	0	2	12	28	294
6	.050	3	3	0	1	1	3	0	11	219
Mooyah Bay										
2	.082	0	2	2	0	0	0	0	4	49
3	.115	1	1	2	0	1	1	6	11	96
4	.079	0	1	6	0	0	1	3	11	139
Sitka spruce										
Franklin River										
2	.102	1	3	0	0	1	0	0	5	49
3	.618	0	71	49	0	115	0	0	235	380
4	.489	0	11	2	0	11	0	0	24	49
6	.492	1	28	25	0	34	0	7	95	193
Port Renfrew										
2	.234	4	0	2	1	2	0	2	11	47
3	.163	6	2	3	3	14	0	0	28	172
4	.101	6	2	1	0	0	0	0	9	89
6	.152	10	1	10	0	7	0	7	3	230
Mooyah Bay										
2	.104	2	2	1	0	0	0	0	5	48
3	.105	5	0	1	2	9	1	2	20	191
4	.000	0	0	0	0	0	0	0	0	47
Western hemlock										
Franklin River										
2	.024	0	0	2	0	0	0	0	2	82
4	.015	0	1	0	0	0	0	1	2	136
6	.116	3	2	6	0	0	0	4	15	129
Port Renfrew										
3	.077	9	0	6	0	0	0	1	16	208
6	.061	5	1	3	1	0	1	0	11	181

*defect frequency index d_f = (no. defects) / (no. trees observed)

APPENDIX 3. Average branch dimensions in Franklin River plots by species and spacing at age 25 years

Species and spacing	No. live branches	No. dead branches	Total no. branches	Diameter of branches (cm)	Live crown (%)	dbh (cm)	Total ht (m)
Douglas-fir							
2.7 × 2.7 m	0	8	8	2.7	55	19.7	16.4
3.7 × 3.7 m	1	7	8	3.0	65	25.2	16.8
4.6 × 4.6 m	2	7	9	3.5	70	29.2	16.3
Sitka spruce							
2.7 × 2.7 m	3	6	9	2.7	64	15.7	9.0
3.7 × 3.7 m	7	3	10	3.3	78	19.5	9.4
4.6 × 4.6 m	9	1	10	3.8	76	19.6	8.6
Western hemlock							
2.7 × 2.7 m	4	2	6	2.5	73	15.8	11.5
3.7 × 3.7 m	7	0	7	2.8	84	18.9	11.3
4.6 × 4.6 m	5	1	6	2.7	85	20.6	12.3
Western redcedar							
2.7 × 2.7 m	4	1	5	2.4	75	14.2	8.4
3.7 × 3.7 m	4	0	4	2.9	76	15.4	7.7
4.6 × 4.6 m	6	0	6	3.0	82	17.1	8.3